Space use and habitat use by moose in relation to OHV routes on the Yakutat forelands

Preliminary results of a GIS-based analysis conducted for the U.S. Forest Service

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SUMMARY

The objective of this study was to evaluate whether off-highway vehicle (OHV) routes affect space use and habitat use patterns by moose (*Alces alces*) on the Yakutat forelands. We utilized a dataset of 9,752 GPS-collar locations that were collected from 18 adult moose in Yakutat over a period of 2 years (2003-2004). We developed individual- and population-level resource selection functions (RSF) to estimate the relative importance of route and habitat variables in explaining the occurrence of moose within individual home-ranges. Analyses were conducted for a Summer period of very low OHV activity to evaluate the potential impacts of route presence, and a Late Fall period of high OHV activity to evaluate the potential impacts of frequent OHV use and associated hunting activity. If OHV routes influenced space use, we expected the main route variable, distance to route, to be an important predictor of moose occurrence. If OHV routes influenced habitat use, we expected the route variable to interact with one of 6 habitat variables to explain moose occurrence.

Individual-level analyses suggested that routes influenced space use and/or habitat use for 12 of 18 animals in Summer, when there was virtually no OHV activity. For Late Fall, individual-level analyses showed that routes influenced space use and/or habitat use for 16 of 17 animals. Most animals showed effects of routes on habitat use (i.e., route-habitat interaction), which limited interpretation of the magnitude and direction of space use (i.e. avoidance). Twelve of 16 seasonal home ranges essentially lacking routes showed evidence that space and/or habitat use were affected by routes present outside of home ranges.

Population-level analyses suggested that space use was negligibly influenced by routes in Summer or Late Fall, but routes specifically influenced the use of willow habitats during Late Fall. Whereas moose were more likely to occupy willow habitats beyond approximately 800m of routes, this pattern was not evident below this threshold.

Although the nature of these data limits the conclusions of our analyses, these preliminary findings provide sufficient evidence that OHV routes and activity may influence the spatial distribution and habitat use by moose at multiple spatial scales. Our findings collectively suggest that the physical placement of new and existing OHV routes on the Yakutat landscape is an important consideration for management. This provides ample justification for further investigating the extent to which OHV routes impact moose habitat and/or affect foraging opportunities in optimal habitats. We suggest that, until such information is available, an appropriate interim management strategy would be to continue monitoring OHV use and limit further expansion of OHV routes into the Yakutat forelands.

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OBJECTIVE

The objective of this study was to evaluate whether off-highway vehicle (OHV) access affected space use and habitat use by moose (*Alces alces*) on the Yakutat forelands.

BACKGROUND

The influence of transportation routes on moose (*Alces alces*) includes direct and indirect effects. Mortality and injury of moose in transportation corridors have been well established in North America and Europe (Bangs et al. 1989, McDonald 1991, Canfield et al. 2001, Krisp et al. 2002, Ball and Dahlgren 2002, Seiler 2005). Other potential direct effects include displacement from transportation routes which may lead to unnecessary energy expenditure and heat stress, which, although less important in Alaska, is something ungulates are particularly sensitive to (Canfield et al. 2001). In a more indirect sense, moose may also avoid transportation routes or alter their use of habitats near roads, and this could have possible consequences for forage availability, individual fitness, and population productivity. With respect to these indirect effects, it is important to understand such phenomena during the summer and fall periods (Canfield et al. 1999). Although traditionally there has been a focus on the survival and body-fat attrition of moose during winter, summer and fall are arguably more critical periods: adult males must build a fat reserve for the fall breeding season and antler growth, moose calves must have secure habitat to reduce predation without comprising the nutrional quality of forage available to adult females (Bowyer et al 1999), which must obtain forage to meet the demands of lactation, recover from weight loss the previous winter, and build fat reserves during for the coming winter (Franzmann and Schwartz 1997).

Unfortunately, there are only a few studies that have focused on indirect effects of transportation routes on moose distribution, and these studies differ in scale and conclusions. Schneider and Wasel (2000) surmised that while access is generally assumed to have a negative influence on moose locally, they found that at the regional scale, the density of moose was positively associated with road density. Likewise, Remm and Ludd (2003) found that the density of moose was negatively related to distance to roads at regional scales in Estonia. In contrast, in Denali National Park, during a period in which visitor use numbers increased 8-fold, the number of moose observed along the Denali road corridor declined by >50% (Burson et al. 2000). Fewer moose were observed within 100 m of the road, but these differences were not observed in 100-500-m distance categories. These patterns were the only trends detected among 3 ungulate species studied.

The effects of transportation routes, however, must take into consideration the spatial configuration of habitats because routes and habitat availability may interact in complex ways to influence moose distribution. Yost and Wright (2001) found that moose sightings were less than expected out to a distance of 1200 m from the Denali road; however, the authors did not include in their analysis the spatial pattern of forage availability, which they believed more thoroughly explained their finding. Likewise, Ball and Dahlgren (2002) found that the availability of preferred habitats in Sweden (Pinus spp.) near roads, coupled with the observation that moose would not readily cross roads, led to a consistent clumping in the distribution of moose within 3 km of roads. Seiler at al. (2003) also showed a 3-fold increase in pellet density near a new road that migrating animals were reluctant to cross. Somewhat along similar lines, Kunkel and Pletscher (2000) found that moose were killed by wolves in areas that tended to have significantly lower road density; illustrating the importance of understanding how roads and road access may interact in complex ways with other ecological factors important for moose survival.

In 2004, to complement an ongoing study of moose habitat use conducted by the U.S. Forest Service and University of Alaska Fairbanks, the Yakutat Ranger District and a consultant (LSD Inc., Arizona) conducted a preliminary analysis of moose distribution in relation to transportation routes in the Yakutat forelands (Logan Simpson Design 2004). Analysis of >4000 locations (n=15 animals) suggested that moose were using habitats more than 2 km from transportation routes more than expected and using habitats within 2 km of roads less than expected. The analysis remained inconclusive, however, because the analysis was exploratory, it did not directly take into account the interaction between habitat and routes, and included assumptions that were not tested. Therefore, in consultation with the Yakutat Ranger District and Juneau Forestry Sciences Laboratory, we re-analyzed a larger data set (n=9752 locations from 18 individuals) using a more robust multivariate approach. We developed resource selection functions (RSF) to estimate the relative importance of route and habitat variables in explaining the occurrence of moose at the scale of individual *home-ranges*. We developed both individual-level RSF's to account for individual variation and population level RSF's to evaluate generalized population patterns.

METHODS

Seasonality

We identified two primary seasons of interest based on our knowledge of moose biology, through consultation with moose biologists, and from the scientific literature (Franzmann and Schwartz 1997) (Table 1). In Summer (July 1 - Aug 7), OHV activity was minimal and hence this was primarily a test for avoidance of access routes. In contrast, in Late Fall (Oct 08 –Nov 15), OHV activity and hunting peaked and hence, this was primarily an evaluation of access-route avoidance plus the potential effects of direct displacement. Subsistence hunting began in Yakutat 08 October and area-wide general hunting began 15 October.

Animal GPS-Location Data

We utilized existing data from a cooperative study of moose conducted by the University of Alaska Fairbanks and the Yakutat Ranger District. This moose data set originally consisted of ~40,000 locations originating from 20 animals that were studied from November 2002 – March 2005. We screened GPS location data extensively (Appendix A) because the data set included many spurious locations (e.g. locations after collars dropped or the animal had died) and to achieve consistency with our individual-based analysis. The final dataset consisted of locations from 18 moose (*n*=9752; Table 2), all of which except animal #44 had data for the 2 primary seasons of interest. Data were derived from Summer and Late Fall periods in 2003 or 2004.

Home Range Delineation

We created seasonally-specific kernel home ranges for individual animals. A minimum of 30, and preferably ≥50 locations, were needed to accurately construct either yearly or seasonal kernel home range estimates; our analysis included a minimum of 130 locations. We calculated 99.999 seasonal kernel home ranges using the Home Range Extension (HRE) for ArcGIS9 (beta version 9.x from its creator, Art Rodgers). We used the unit variance option to standardize the variance in the *x* and *y* coordinates. We calculated an initial value for the smoothing parameter *href* (based on Worton 1989 equation) and created initial kernel home ranges. We subsequently lowered *href* in 0.1 increments until a) the home range to split into multiple polygons or b) a lacuna (e.g. gap) appeared within the home range polygon. We then used the level of *href* a step above which the split or lacuna occurred. The 99.999% contours were used to approximate 100% contours (which are not possible to calculate), such that all locations available were effectively included in the kernel home range. The process of reducing *href* essentially "tightened" the polygon around the points to reduce the likelihood of committing a Type I error, which would occur if we included areas that were not used. By using a value of *href* one increment above the value at which polygon segmentation occurred, we reduced the likelihood of a Type II error (not including areas that actually were used). We then clipped the home ranges to the 1:63,000 coastline layer for Alaska in order to eliminate portions of the home range with saltwater.

Randomized Locations

We used the Random Point Generator in the Jennes extension for ArcView (provided by J. Jennes) to create 'random' locations within each seasonal home range. We generated an equivalent number of 'random' locations as 'observed' locations in each seasonal home range.

Habitat Classification

GIS habitat layers incorporated in the analysis were the Forest service TimType layer and a vegetation layer from Glacier Bay National Park (1996). These two layers were similar in classification regimes. Habitat for most of the study area was classified using the TimType layer and habitat in the Dry Bay area was classified using the Glacier Bay vegetation layer (Appendix B). We derived 5 habitat classes: Alder, Willow, Poplar, Conifer, Muskeg, and Other.

Road Classification

We utilized a District road GIS layer that had been updated by District personnel in 2004 using IKONOS imagery. We further verified the status of these roads during the study period of interest through consultation with District personnel who were conducting a road-based inventory. ATV routes were mapped in 2004 with GPS and helicopter support and subsequently digitized as GIS data. We merged these roads and ATV GIS layers into a composite layer; we treated all features as equivalent access routes for our analyses.

Individual-Based Model

Resource selection coefficients for each individual moose were extrapolated using logistic regression procedures performed with SPSS12 and SAS software. Main effects considered in the analysis included route (i.e., roads + atv trails considered jointly), Alder, Willow, Poplar, Muskeg, Conifer, and Other. Data for each animal-season were initially screened for highly correlated variables because logistic regression models are sensitive to colinearities (Hosmer and Lemeshow 2000). If Pearson correlation coefficients of $r > 0.7$ were discovered, only one of the interacting terms was kept in the model. If the main-effect Route interacted with another variable, it was always chosen as the variable to stay in the model. If other habitat variables were correlated, the one that contributed most to the model was selected for inclusion. We performed forward stepwise logistic regression for main effect variables, where entry testing was based on the significance of the score statistic, and removal testing was based on the probability of a likelihood-ratio statistic based on the maximum partial likelihood estimates. P-values for entry and exit were set as recommended by Hosmer and Lemeshow (2000), where $P_{\text{entry}} = 0.15$ and $P_{\text{removal}} = 0.20$, to look for broad trends as well as to allow analysis of a wider range of variables with regards to interactions. If final main-effect models did not include the variable "Route", this was documented, and then Route was added to allow for analysis of interactions. We sequentially added interaction terms to the model based on significance of the individual term within the main effect model, with no other interaction terms present. Most significant terms were added first, and subsequent terms were added if they were significant and would not cause previously entered interaction terms to be removed. P_{removal} for interaction terms was set at $p > 0.05$. We chose this p-value to avoid over-fitting the model, and because we wanted to be conservative when considering interactions, which change the coefficient of the main effect and therefore may limit interpretations. Furthermore, p-values greater than 0.05 exhibited 95% confidence intervals for odds ratios ($\exp(B)$) that overlapped one, indicating that the direction of selection could not be determined due to variance associated with the estimate.

As such, interaction terms were composed of habitat variables that were significant ($p< 0.20$) as a main effect, but not necessarily a significant "Route" main effect. This procedure was used because it is possible that areas near roads may be used similar to 'random' locations (so that route would not be significant in the model), when there actually is a habitat-based effect. For example: if areas near roads contained preferred habitat, they should be used more than expected, but a negative effect of roads may only cause these areas to be used "as expected", but not avoided. By keeping Route in the model, we were able to evaluate the possibility that routes, although not directly influencing space use, could be influencing habitat use by moose.

Population Model
For population-level modeling, we used the same stepwise model selection procedure in SPSS as had been used with individual-based modeling. Screening for colinearities was done for each season, but included the data set from all animals. Initially, we pooled locations from all individuals and ran stepwise regression *without* accounting for individual variation. The concern with this method is that significance of variables may be overstated simply because the sample size is incorrectly determined by the program to be 19,000+ (locations) instead of 18 (moose). It also fails to account for variation associated with individual moose behavior (Nielsen et al. 2002, Marzluff et. al 2004). Therefore, we also ran a stepwise modeling procedure with SAS statistical software, utilizing the macro *glimmix.sas* such that we included a 'random' command to account for individual variation. Finally, we also averaged coefficients from individual-based models to compare individual-model patterns with the SAS model, which accounted for individual variation.

Table 1. We stratified and prioritized analyses on the basis of seasonal home ranges, each of which were influenced by a combination of biological and anthropogenic factors. For each seasonal home range period, we restricted our analysis to a discrete 5-wk analysis period during which we expected little influence of transitions between seasons. This stratification was derived from the findings of an earlier study (Franzmann and Schwartz 1997) and through consultation with moose biologists. Shaded areas represent the 2 periods during which we conducted analyses.

Season	Biological/Anthropogenic Influences	Approx. Time Frame	5-wk Analysis Period	Justification/Comments
Winter	Winter Forage Snow	Nov 15-April 30	None Selected	Not relevant to analysis
Spring	Calving Female Migratory Events Green-Up	April 15-June 14	None Selected	Possibly include in future, but female movement & behavior could confound the analysis
Summer	Post-Calving Summer Forage No hunting/low OHV activity	June 1-Sept 15	July 1 - Aug 7	Test for road avoidance and altered habitat use
Early Fall	Fall Forage No hunting/low OHV activity Male Rut	Sept 1-Oct 30	None Selected	Possibly include in future, but rut-related movements could confound the analysis
Late Fall	Fall forage Hunting/Peak OHV activity	Oct 8 – Nov 30	Oct 8 - Nov 15	Test for road avoidance and/or displacement, and altered habitat use

Table 2. Number of GPS collar locations for 18 moose included in the analysis, subsequent to extensive data screening. The number of locations per season varied due to differences between seasons in GPS location rates and number of days.

	Animal ID (*n* locations)																		
Season	**23**	**24**	**27**	**31**	**32**	**33**	**34**	**35**	**39**	**40**	**41**	**42**	**44**	**45**	**46**	**47**	**48**	**49**	**Total**
Summer	151	150	148	146	142	147	151	152	151	298	290	297	148	152	139	295	299	142	3218
Late Fall	153	153	154	153	154	154	151	156	155	309	302	309	-	151	148	309	155	152	3398
Total	447	449	444	444	439	447	448	453	453	883	880	891	285	446	423	891	601	428	9752

RESULTS

For all models, we summarize below the results of variables that are most relevant to the immediate question of if and how routes effect space use and habitat use by moose. Appendix C and D summarize our findings regarding additional habitat-class variables incorporated into each model. Individual-based RSF's for Summer suggested that Route influenced space use or habitat use for 12 of 18 animals (Table 3). For Late Fall, individual-based analyses showed evidence that routes influenced space use or habitat use for 16 of 17 study animals (Table 4). During Summer and Late Fall, individuals varied in their response to Route, both in terms of the significance and direction (positive or negative) of main effects and interaction terms. The pattern for most animals suggested an influence of routes on habitat use (i.e. interaction between routes and a habitat class variable), which limited interpretation of the magnitude and direction of effects on space use alone (e.g. route). However, of 6 animals whose space use only was affected by Route, 4 exhibited a preference for available habitat that was closer to routes. There were no obvious relationships between patterns at the individual level and either the sex of the animal or the road density (road length/area) in each animal's home range, but it is worthwhile to note that space and/or habitat-use patterns in 12 of 16 seasonal home ranges (11 Summer, 5 Fall) with virtually no OHV routes were apparently influenced by routes outside of home ranges (Table 5).

The "Simple" pooled population models (i.e., stepwise procedure that did not account for individual variation) yielded a significant interaction between Route and 4 habitat variables during Summer, but this pattern was not found when we conducted the procedure using a modeling technique that accounted for individual variation (Table 6). In contrast, both analysis procedures suggested that Route influenced habitat use during Late Fall. These data indicate that the effect of motorized access may be stronger during fall than spring. Notable, however, is that while both the "Adjusted" and "Simple" models for Late Fall include an interaction term between Route and Willow, the direction (positive versus negative) of this interaction is different. This is probably due to the presence of multiple interaction terms in the "Simple" model, each of which confounds the coefficient of the variable Route. It is likely that because the "Simple" model does not account for individual variation, the significance of the other interaction terms was inflated.

When there is a significant interaction, the significance and parameter values of the contributing main-effect variables should not be interpreted directly. The presence of an interaction indicates that all interpretations of a contributing variable need to be made with reference to the other contributing variable(s). Even so, we draw attention to the fact that Route was a significant main-effect variable in the "Simple" Late Fall model, whereas it was an insignificant main-effect in the "Simple" Summer model and the "Adjusted" Late Fall model. This may be an indication that the spatial distribution of moose near routes in the Summer was different than random, but not so in the Fall. The significance of an interaction term, in contrast to a main-effect, indicates that while distance of moose to routes may not be different than random, use of (i.e. distance to) Willow is influenced by distance of moose to routes. Examination of scatter plots showing the probability that a location is used by moose as a function of distance to Willow and distance to routes confirms this (Fig 1): when moose are in relatively close proximity to routes, moose occur relatively further from willow patches. Likewise, when moose are relatively far from routes, moose occur relatively close (or in) willow patches. This transition in the use of willow appeared to occur within a zone that was approximately 500-800m from routes. Our analysis accounts for habitat availability – this is not simply a function of where willow occurs on the Yakutat landscape.

Table 3. Results of individual-based RSF for Summer (*n*=18 animals). Shown below are only the model variables that have direct relevance to an evaluation of space use (Route) and habitat use (Road x Habitat Class). See Appendix C for full model results. Variable coefficients listed below are significant at the $p<0.05$ level, unless otherwise noted. Positive Route coefficients indicate avoidance of routes, for individual-based models that do not in include any interaction terms.

Animal ID	**Route**	**Route x Alder**	**Route x Willow**	**Route x Poplar**	**Route x Muskeg**	**Route x Conifer**	**Route x Other**
27	0.721	-0.746	0	0	0	0	0
32	0	0	0	0	0	0	0
34	-0.647†	2.352	0	0	0	0	0
35	0	0	0	0	0	0	0
39	-0.258	0	0	0	0	0	0
40	1.167	0	0	0	0	0	-0.580
42	0.315†	0	0	-0.600	0	-0.125	0
44	0	0	0	0	0	0	0
45	-2.083	0	0	1.166	0	0	0
48	-0.660†	0	4.769	0	0	0	0
31	-0.653	0.223	0	0	0	0	0
46	0.552	0	0	0	0	0	-1.446
33	-1.102†	1.234	0	0	2.996	0	0
24	-0.720	0	0	0	0	0	0
49	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0
41	-0.160	0	-0.144	0	0	0	0
23	0	0	0	0	0	0	0

† Indicates Route variable was initially non-significant as main effect but maintained in model to evaluate interaction terms

Table 4. Results of individual-based RSF for Late Fall (*n*=17 animals). Shown below are only the model variables that have direct relevance to an evaluation of space use (Route) and habitat use (Road x Habitat Class). See Appendix C for full model results. Variable coefficients listed below are significant at the p<0.05 level, unless otherwise noted. Positive Route coefficient indicates avoidance of routes for individual-based models that do not in include any interaction terms.

Animal ID	**Route**	**Route x Alder**	**Route x Willow**	**Route x Poplar**	**Route x Muskeg**	**Route x Conifer**	**Route x Other**
27	0.519	0	0	0	0	0	0
32	0	0	0	0	0	0	0
34	-0.463	1.152	0	0	0	0	0
35	-0.183†	0	0	-0.308	0.594	0	0.358
39	0.262	0	0	0	0	0	0
40	0.729	0	0	-0.209	12.263	0	1.045
42	0.260	0	-0.496	0	0	0	0
44					No data		
45	0.406	0	0	0	0	-0.576	0
48	1.256	0	0	0	0	-1.169	-0.991
31	-0.307	0	0	0	0	0	0
46	-1.325	0	0	0.615	0	0	0.819
33	-0.072†	0	0	3.204	0	0	0
24	-1.668	0	-0.554	0	0	0	0.629
49	-0.311	0	0	0	0	0	0
47	-0.233†	0	0	0	0	0	1.469
41	1.453	0	0	0	-0.116	0.203	0
23	1.039	0	0	0	-3.039	0	0

† Indicates Route variable was initially non-significant as main effect but maintained in model to evaluate interaction terms

Table 5. Summary table of evidence for the influence of routes on space use and habitat use, based on individual-level RSF's (*n*=18 animals). "Yes" indicates statistical significance, "No" indicates a lack of evidence, and "Possible" for space-use indicates that the space-use variable (Route) met criteria for inclusion in model (p<0.15) but was ultimately not interpretable due to significance of an interaction.

Moose ID	Space Use Summer	Space Use Fall	Habitat Use Summer	Habitat Use Fall	#Km Routes in Home Range Summer	# Km Routes in Home Range Fall	Sex
27	Possible	Yes	Yes	No	0.000	10.831	F
32	No	No	No	No	0.000	0.000	F
34	No	Possible	Yes	Yes	0.000	7.531	F
35	No	No	No	Yes	0.000	1.275	M
39	Yes	Yes	No	No	0.000	9.930	F
40	Possible	Possible	Yes	Yes	0.000	0.000	F
42	No	Possible	Yes	Yes	0.000	0.959	F
44	No	-	No	-	0.000	-	M
45	Possible	Possible	Yes	Yes	0.000	42.661	F
48	No	Possible	Yes	Yes	0.000	0.000	M
31	Possible	Yes	Yes	No	0.839	6.793	F
46	Possible	Possible	Yes	Yes	2.742	94.760	M
33	No	No	Yes	Yes	7.217	7.670	F
47	No	No	No	Yes	11.673	18.579	M
24	Yes	Possible	No	Yes	12.072	13.879	F
41	Possible	Possible	Yes	Yes	24.056	0.000	F
49	No	Yes	No	No	25.844	7.181	M
23	No	Possible	No	Yes	96.492	25.201	F

Table 6. Results of population-based RSF's for Summer and Late Fall. Three types of population-based RSF are presented: (1) a model with pooled radio-telemetry data; (2) an adjusted model with pooled data but incorporating a random error term for individual animals; and (3) a model derived from averaging individual-level coefficients. Shown below are only the model variables that have direct relevance to an evaluation of space use (Route) and habitat use (Road x Habitat Class). See Appendix C for full model results. Only the cells with values listed are significant at the $p<0.05$ level, unless otherwise noted.

Population Model Type	**Season**	**Route**	**Route x Alder**	**Route x Willow**	**Route x Poplar**	**Route x Muskeg**	**Route x Conifer**	**Route x Other**
Simple (Pooled)	Summer	-0.079†	-	0.024	0.032	-	-	-
	Fall	-0.011	-	0.030	-	-0.017	0.026	-
Adjusted (Random-effects)	Summer	-	-	-	-	-	-	-
	Fall	0.1762†	-	-0.1549	-	-	-	-
Averaged Individual	Summer	-0.19602	0.170107	0.256966	0.03141	0.16644	-0.00693	-0.11253
	Fall	0.080	0.072	-0.062	0.194	0.571	-0.091	0.196

† Indicates Route variable was initially non-significant as main effect but maintained in model to evaluate interaction terms

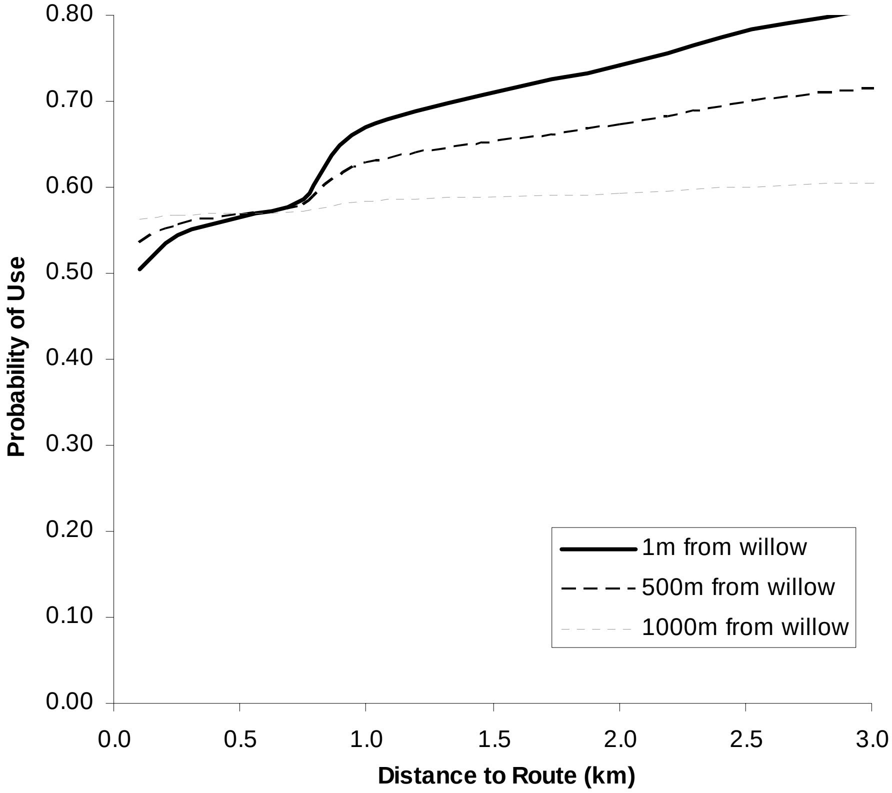

Fig 1. Probability a location is used during the Fall analysis period as a function of distance to Route at three distances from Willow, as estimated from the "adjusted" resource selection function model for moose in the Yakutat forelands, 2002-2003. The probability of moose using willow generally increased further from routes. Whereas moose were more likely to be found in close proximity to willow beyond approximately 800m of routes, this pattern was not evident below this threshold.

DISCUSSION

Data Biases

Interpretations of these data and inferences should be made with caution, because although our population-level RSF accounted for the problems that typically result from simple pooling of data (i.e. psuedorpelication), there were at least 3 other sources of error associated with this analysis: GPS locations, vegetation mapping, and route mapping and classification. In this analysis we attempted to minimize GPS error by using a Euclidean distance-based metric, which helps eliminate classification errors resulting from variation in accuracy of GPS collars. If habitat types were classified incorrectly or inconsistently, then the likelihood of finding route × habitat interaction was low and/or results could have been spurious. We currently have no data available to evaluate the accuracy of the 2 habitat maps utilized in this analysis. Likewise, there is currently no way to know if routes were mapped correctly or completely in the study area, particularly ATV routes. We estimate that up to 25% of ATV routes in the Yakutat forelands may have remained unmapped (C. Grove, pers. comm.). Perhaps most importantly, the absence of quantitative data pertaining to traffic levels, or pattern of use, of roads versus ATV trails was a major disadvantage. Regardless of route type, routes with relatively higher use were classified the same as routes with little or no use. Previous studies of the effects of transportation routes on wildlife have shown that level of use is a primary determinant of avoidance behavior. Without this knowledge, there is extensive "noise" to contend with in attempting to determine effects of motorized access, and this is likely a primary reason why we found such extensive variation in individual responses to routes.

Evidence for Effects on Space Use

We documented evidence that routes influenced space use by moose at 2 scales and in 3 ways. At the landscape scale, route occurrence and OHV activity had measurable impacts on home-range use by most individuals, even when routes were essentially absent from home ranges. These individuals may have selected or modified home ranges based on route occurrence and/or OHV activity, suggesting some moose may have avoided portions of the landscape with routes altogether. At the home range scale, the spatial distribution of most individuals was possibly influenced by the proximity to routes, but this will require further investigation because space use patterns were influenced not just by routes but typically by habitat context as well. Also at the home range scale, moose were more likely to be found in close proximity to Willow habitat when further (e.g. > 800m) from routes during Late Fall. This suggests moose may have avoided Willow near routes at least during periods with frequent OHV use and/or hunting activity, however it was not possible with these data to disentangle which of these 2 related activities moose were primarily influenced by.

A conclusive statement about whether or not moose were avoiding routes was difficult to ascertain due to the nature of these data and the complexity of the interaction among habitat and route variables. In addition, individual variation limited population-wide generalizations about avoidance. For example, some animals in our sample pool appeared to be selecting locations closer to routes than expected at random. In any case, we caution that a focus on avoidance alone may not be a very effective management strategy: avoidance of routes and associated transportation activity are expected to be common among wildlife species and may not necessarily affect their use of habitats, an individual's fitness or population trajectories.

Evidence for Effects on Habitat Use

Routes influenced the use of 6 habitat variables by moose, and both population level and most individual-level analyses confirmed this. Individual-based analyses suggested that moose shifted their occupancy of habitat patches depending on the proximity to routes in both Summer and Late Fall periods. The Summer pattern is particularly noteworthy: OHV activity was putatively low and hunting was essentially non-existent during this period. This suggests that most individuals were selecting habitats relative to the presence of routes alone, and not OHV activity *per* se. Among our individual-based analyses, the importance of different habitat elements (e.g. Willow, Muskeg, Conifer) varied extensively. Although individual patterns will need to be examined on a case-by-case basis to explore possible reasons for such variation, a preliminary evaluation suggests this was not related to sex or the density of roads in home ranges, but perhaps related to other factors like individual behavior, level of habituation, and life history.

At the population level, the use of Willow by moose was affected by routes in Late Fall when OHV use and hunting peaked. As previously mentioned, this pattern may be attributable to moose avoiding areas where hunting was occurring, and not necessarily due to direct avoidance of OHV activity. Unlike the analyses of individuals, we found little evidence at the population level that moose were affected simply by the presence of routes (e.g., in Summer). Still, the significant influence of routes on space or habitat use of some individuals could have important consequences for the moose population, especially if it reduces foraging opportunities or animal fitness.

We discovered discrepancies in habitat-use patterns as revealed by individual versus population-level analyses, and we suspect that this disparity illustrates a common shortcoming of population-level analyses. That is, despite our finding that nearly every animal showed a strong tendency to change its habitat use in relation to routes in Summer, this pattern was effectively masked at the population level because of variability among individuals. Alternatively, this disparity may have resulted from our inability to classify routes according to levels of use. Perhaps habitat use patterns at the population level were affected along routes where higher OHV activity occurred during Summer. Nevertheless, our findings suggest that moose were altering their use of the Yakutat forelands under some conditions, and additional investigation is needed to establish whether OHV routes impacted the availability of high-quality habitat and/or foraging opportunities for moose.

MANAGEMENT IMPLICATIONS

These preliminary findings provide sufficient evidence that OHV routes and activity may have influenced the spatial distribution and habitat use by moose at multiple spatial scales. The nature of these data limits the conclusions of our analyses. Still, our findings collectively suggest that the physical placement of new and existing OHV routes on the Yakutat landscape is an important consideration for management. This provides ample justification for further investigating the extent to which OHV routes impact moose habitat and/or affect foraging opportunities in optimal habitats. We suggest that, until such information is available, an appropriate interim management strategy would be to continue monitoring OHV use and limit further expansion of OHV routes into the Yakutat forelands.

PROPOSED FUTURE ACTIVITIES

1. Additional statistical analyses will be conducted on these data and an additional report will be submitted on or before February 31, 2006. These analyses include:

- Re-evaluating results after accounting for differences in OHV and
- The population level RSF with a random-effects error term will be refined into a final population-level RSF to help evaluate trends at the population level. We will conduct this analysis in a more advanced (raster –based) GIS format to facilitate its use as a predictive tool in the future.

- More detailed analyses of individual interaction terms will be evaluated to help more clearly understand how routes are influencing selection patterns for or against habitat classes.

- The final population-level RSF will be utilized to quantify the impacts of access routes on effective habitat. Specifically this RSF will yield estimates of the area of habitat influenced per km of OHV trail.

- Movement patterns of moose in relation to roads will be evaluated. In particular, we will conduct tests for repulsion/attraction responses to roads (*sensu* Mace and Waller 2000).

2. We suggest initiating a study that is focused specifically on testing hypotheses pertaining to moose and OHV access routes, as well as help develop a spatially explicit tool to manage OHV access in the future. A UAS graduate student could be recruited to carry out this study in cooperation with the Yakutat Ranger District. The study would have 5 components and would not require the use of GPS radio-collar data:

- Quantify the relative use of OHV routes using trail counters established at key locations (e.g. junctions). GIS modeling (e.g. kreiging) could then be used to derive a complete surface cover of OHV use. Alternatively, or possibly as an additional data source, conduct a sociological survey among Yakutat residents/OHV users and include a participatory mapping component to derive estimates of relative use on the landscape
- Obtain habitat class-specific estimates of relative forage biomass in the Yakutat forelands with the help of a nutrition lab.
- Refine the population-level RSF model developed above, this time incorporating forage biomass and estimates of route use to predict in a spatially explicit manner the occurrence of moose on the Yakutat forelands.
- Conduct pellet surveys using a stratified-random sampling design to validate the RSF model. Refine the model, and apply it in the future as a spatially explicit tool to understand, in terms of effective habitat area gained or lost, the consequences of closing access routes, creating new access routes, putting limits on the frequency of use, and/or weighing options in management plans.
- As an additional possibility, non-invasive endocrinological surveys of pellets collected at different distances from access routes could be conducted to evaluate evidence of physiological stress in relation to OHV access and relative use (Creel et al. 2003).

3. GIS curriculum that focuses on the Yakutat-OHV case study and incorporates the non-proprietary elements of project data will continue to be developed at the University of Alaska

Southeast. A GIS learning module that incorporates moose data has already been tested this fall and S. Pyare will continue to refine this module through December 2006.

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APPENDIX A. DATA SCREENING AND PROCESSING

We processed radiotelemetry data in the following ways:

- Locations with no lat/long (i.e. unsuccessful fixes) were removed
- Locations with incorrect dates were removed
- Locations with incorrect coordinates were removed
- Duplicate locations were removed duplicates.
- Locations that occurred before and after the GPS collar was no longer on the animal were removed. We initially believed that the data file given to us only contained locations when the collar was actually on the animal. However, because of abnormalities of kernel home ranges for moose #52, we suspected that locations in the data extended beyond the time the animal was wearing the collar. If the collar is not on the animal, many locations close together would be recorded in one location, which would introduce severe bias into the dataset for the calculation of home ranges and resource selection. We inspected all animal datasets to determine at what point movements became non-linear and distances between locations became extremely small. We removed locations for three individual moose (moose id # 44 (3 days), 48 (1 day), 52(128 days).
- Data collected at intervals farther apart than 6 hours were eliminated from analysis (not including effects of intermittent GPS failure). 10 individuals had cycle changes on June 9th, 2004 such that locations were collected at some point every 7-9 days until collars were recovered. Due to changes in sampling, locations for these individuals after this date were not used in the analysis.
- 4 Individuals (#44, 46, 47, 48) had data collected at 3 hour intervals (8 locations per day). The remaining 16 individuals had data collected at 6 hour intervals (4 per day). The sampling interval can affect the estimation of kernel home ranges, and date is considered when kernels are created. If individuals are the experimental unit, time periods are defined, and the same sampling protocol is applied to all individuals in a random or systematic in nature, the effects of autocorrelation are not of great concern (Otis and White 1999). Thus, we preferred to keep the sampling interval constant across animals to minimize variation and only used locations that followed the 6 hour schedule. Therefore, locations that followed the same hourly schedule were extracted from the 4 individuals for which data was collected at 3-hr intervals.
- If an individual had only partial season data, that data was not used and the animal was excluded from the analysis for that season. Four animals had locations for all seasons in 2003 and 2004 (#40, 41, 42, 47). One animal had locations for all seasons in 2004 (49). One animal had locations for all seasons in 2003 and 1 season (summer) in 2004 (47). One animal had locations for only 2 seasons (summer, early fall) in 2003 (44), and two animals did not have locations for any season in the analysis (21, 52). The rest of the individuals had locations for all three seasons in 2003.

APPENDIX B. Habitat classification of vegetation types in Tongass National Forest TimType Vegetation layer (for the Yakutat forelands west of the Alsek river) and the National Park Service Vegetation layer (for the adjoining Dry Bay area)

USFS TIMTYP Code	Vegetation Type	Habitat Class
NA	ALDER BRUSH	Alder
F A	LOW PROD DUE TO ALDER	Alder
F H 23	HEMLOCK	Conifer
F H 34	HEMLOCK	Conifer
F H 35	HEMLOCK	Conifer
F H 44	HEMLOCK	Conifer
F H 45	HEMLOCK	Conifer
F H 46	HEMLOCK	Conifer
F X 3	HEMLOCK-SPRUCE	Conifer
F X 34	HEMLOCK-SPRUCE	Conifer
F X 35	HEMLOCK-SPRUCE	Conifer
F X 36	HEMLOCK-SPRUCE	Conifer
F X 4	HEMLOCK-SPRUCE	Conifer
F X 43	HEMLOCK-SPRUCE	Conifer
F X 44	HEMLOCK-SPRUCE	Conifer
F X 45	HEMLOCK-SPRUCE	Conifer
F X 46	HEMLOCK-SPRUCE	Conifer
F S	SPRUCE	Conifer
F S 1	SPRUCE	Conifer
F S 13	SPRUCE	Conifer
F S 2	SPRUCE	Conifer
F S 23	SPRUCE	Conifer
F S 26	SPRUCE	Conifer
F S 33	SPRUCE	Conifer
F S 34	SPRUCE	Conifer
F S 35	SPRUCE	Conifer
F S 36	SPRUCE	Conifer
F S 37	SPRUCE	Conifer
F S 4	SPRUCE	Conifer
F S 43	SPRUCE	Conifer
F S 44	SPRUCE	Conifer
F S 45	SPRUCE	Conifer
F S 46	SPRUCE	Conifer
F S 47	SPRUCE	Conifer
F M	LOW PROD DUE TO MUSKEG MEADOW	Muskeg
NM	MUSKEG MEADOW	Muskeg
CBRAB	other	Other
F W	other	Other
F X	other	Other

F Z 1	other	Other
F Z 13	other	Other
F Z 2	other	Other
F Z 23	other	Other
F Z 24	other	Other
F Z 3	other	Other
F Z 33	other	Other
F Z 34	other	Other
F Z 35	other	Other
F Z 44	other	Other
F H	other	Other
F L	other	Other
F R	other	Other
F S	other	Other
NB	other	Other
NC	other	Other
ND	other	Other
NG	other	Other
NH	other	Other
NI	other	Other
NK	other	Other
NL	other	Other
NN	other	Other
NO	other	Other
NP	other	Other
NR	other	Other
NS	other	Other
NU	other	Other
NW	other	Other
NX	other	Other
	other	Other
F P	BLACK COTTONWOOD (POPLAR)	Poplar
F P 1	BLACK COTTONWOOD (POPLAR)	Poplar
F P 13	BLACK COTTONWOOD (POPLAR)	Poplar
F P 2	BLACK COTTONWOOD (POPLAR)	Poplar
F P 23	BLACK COTTONWOOD (POPLAR)	Poplar
F P 3	BLACK COTTONWOOD (POPLAR)	Poplar
F P 33	BLACK COTTONWOOD (POPLAR)	Poplar
F P 34	BLACK COTTONWOOD (POPLAR)	Poplar
F P 35	BLACK COTTONWOOD (POPLAR)	Poplar
F P 44	BLACK COTTONWOOD (POPLAR)	Poplar
F P 45	BLACK COTTONWOOD (POPLAR)	Poplar
F T	LOW PROD DUE TO WILLOW	Willow
NT	NON FOREST WILLOW	Willow

NPS Primary Veg.Class	Land Cover Type	Habitat Class
15	Closed Red Alder Forest	Alder
22	Closed Tall Alder	Alder
2	Hemlock Closed	Conifer
5	Hemlock Open	Conifer
51	Pine - not peatland	Conifer
1	Spruce Closed	Conifer
4	Spruce Open	Conifer
8	Spruce Woodland	Conifer
3	Spruce-Hemlock Closed	Conifer
7	Spruce-Hemlock Open	Conifer
12	Hemlock/Spruce, Woodland Stunted Peatland	Muskeg
11	Lodgepole Pine, Woodland Stunted Peatland	Muskeg
32	Open Low Shrub Peatland	Muskeg
45	Aquatic	Other
46	Bare	Other
33	Dryas Dwarf Shrub	Other
37	Elymus	Other
34	Ericaceous Dwarf Shrub	Other
35	Ericaceous Dwarf Shrub - Forb meadow	Other
44	Halophytic Sedge Marsh	Other
100	Human disturbance	Other
13	Krummholz	Other
39	Mesic Herbaceous	Other
48	Moss/Lichen	Other
31	Open Low Shrub	Other
40	Uplifted Graminoid Forb	Other
42	Wet Graminoid Forb	Other
14	Cottonwood, Closed	Poplar
16	Cottonwood, Open	Poplar
17	Cottonwood, Woodland	Poplar
19	Spruce-Cottonwood, Closed	Poplar
20	Spruce-Cottonwood, Open	Poplar
21	Spruce-Cottonwood, Woodland	Poplar
28	Closed Low Willow	Willow
25	Closed Tall Alder-Willow	Willow
23	Closed Tall Willow	Willow
29	Open Low Willow	Willow
30	Open Low Willow-Herbaceous	Willow
49	Open Tall Alder-Willow	Willow
50	Open Tall Willow	Willow

APPENDIX C. Coefficients, Model Significance, and Hosmer and Lemeshow goodness-of-fit significance (higher values = better fit) for individual-based models. Measures are distance-based, so positive coefficients indicate avoidance. Correlated variables (x) were not included in model-building. Coefficients of “0” indicate terms removed from the model due to lack of significance. P-values for all non-interacting main effects and interaction terms are $p < 0.05$.

Season	ID	SEX	Route	Alder	Willow	Poplar	Muskeg	Conifer	Other	Route	RxA	RxW	RxP	RxM	RxC	RxO	SIG.	FIT
SUMR	23	F	29140.48	x	x	0	-2.015	0	0	0	0	0	0	0	0	0	0.000	0.935
SUMR	24	F	3621.61	x	0.578	0	-13.321	0	-0.773	**-0.720**	0	0	0	0	0	0	0.000	0.163
SUMR	27	F	0.00	2.059	x	0	0	0.483	0	0.721	-0.746	0	0	0	0	0	0.001	0.012
SUMR	31	F	244.86	-1.549	0	0	-5.165	0	1.409	-0.653	0.223	0	0	0	0	0	0.000	0.120
SUMR	32	F	0.00	0	x	0	0	-1.040	0	0	0	0	0	0	0	0	0.014	0.063
SUMR	33	F	2121.79	0.976	0	-0.176	-3.182	x	0	-1.102*	1.234	0	0	2.996	0	0	0.000	0.433
SUMR	34	F	0.00	-12.424	0	-2.453	3.344	x	0	-0.647*	2.352	0	0	0	0	0	0.000	0.000
SUMR	35	M	0.00	-2.207	0.284	x	0	x	0	0	0	0	0	0	0	0	0.000	0.271
SUMR	39	F	0.00	x	-2.587	0	-8.084	x	x	**-0.258**	0	0	0	0	0	0	0.000	0.751
SUMR	40	F	0.00	0	0	0	-6.842	0	2.266	1.167	0	0	0	0	0	-0.580	0.000	0.146
SUMR	41	F	15880.01	0.678	1.110	-0.979	0	-0.676	0	-0.160	0	-0.144	0	0	0	0	0.000	0.002
SUMR	42	F	0.00	0	x	0.889	x	0.187	-2.298	0.315*	0	0	-0.600	0	-0.125	0	0.000	0.000
SUMR	44	M	0.00	x	x	-0.542	-5.088	0	-1.064	0	0	0	0	0	0	0	0.003	0.001
SUMR	45	F	0.00	-1.831	0	-4.572	-5.864	0	1.482	-2.083	0	0	1.166	0	0	0	0.000	0.818
SUMR	46	M	762.15	-0.540	x	x	0	0	5.156	0.552	0	0	0	0	0	-1.446	0.000	0.004
SUMR	47	M	8848.85	0	0	0	0	-0.147	1.050	0	0	0	0	0	0	0	0.000	0.000
SUMR	48	M	0.00	x	-23.649	-0.495	1.969	0	0	-0.660*	0	4.769	0	0	0	0	0.000	0.294
SUMR	49	M	7339.65	0.157	-1.458	x	0	-2.476	0	0	0	0	0	0	0	0	0.000	0.000
FALL	23	F	7711.60	0.233	0	0	0.549	0	0	1.039	0	0	0	-3.039	0	0	<0.000	0.649
FALL	24	F	4246.92	x	0.149	x	0	2.864	-0.162	-1.668	0	-0.554	0	0	0	0.629	<0.000	0.131
FALL	27	F	3335.81	-2.039	x	0	0	-0.226	-2.771	**0.519**	0	0	0	0	0	0	<0.000	0.388
FALL	31	F	2078.62	x	x	0	0	4.456	x	**-0.307**	0	0	0	0	0	0	<0.000	0.342
FALL	32	F	0.00	-2.188	x	0.885	-12.223	0	-1.484	0	0	0	0	0	0	0	<0.000	0.000
FALL	33	F	2362.36	x	1.189	-14.431	x	x	0	-0.072*	0	0	3.204	0	0	0	<0.000	0.009
FALL	34	F	2274.23	-1.584	x	-1.753	0	x	3.833	-0.463	1.152	0	0	0	0	0	<0.000	0.132
FALL	35	M	397.94	x	x	1.417	-9.169	1.117	-1.440	-0.183*	0	0	-0.308	0.594	0	0.358	<0.000	0.251
FALL	39	F	3078.37	0	-1.772	0	0	1.465	0	**0.262**	0	0	0	0	0	0	<0.000	0.366
FALL	40	F	0.00	0	0	0.520	-61.835	0	-4.571	0.729	0	0	-0.209	12.263	0	1.045	<0.000	0.001
FALL	41	F	746.12	-1.876	0	-2.621	0.011	-0.886	-2.511	1.453	0	0	0	-0.116	0.203	0	<0.000	0.055
FALL	42	F	2896.44	-1.307	0.551	-1.396	0	x	-1.077	0.260	0	-0.496	0	0	0	0	<0.000	0.025
FALL	44	M	**NO DATA FOR THIS SEASON**															
FALL	45	F	12883.53	0	-0.746	0.799	1.166	-0.482	-3.285	0.406	0	0	0	0	-0.576	0	<0.000	0.000
FALL	46	M	28049.07	x	0	-2.155	0	0	-1.917	-1.325	0	0	0.615	0	0	0.819	<0.000	0.869
FALL	47	M	12048.02	x	x	0	-1.440	0	-0.988	-0.233*	0	0	0	0	0	1.469	<0.000	0.002
FALL	48	M	0.00	0	0	x	-9.828	5.046	4.097	1.256	0	0	0	0	-1.169	-0.991	<0.000	0.173
FALL	49	M	2183.06	0	0	x	0	0	0.676	**-0.311**		0	0	0	0	0	0.008	0.075

* Route was not significant as a main effect, but kept in the model to investigate interaction of variables

APPENDIX D. Comparison of coefficients derived from 3 alternative population-based models.

Population Model	Alder	Willow	Poplar	Muskeg	Conifer	Other	Route	RxA	RxW	RxP	RxM	RxC	RxO	Constant
SUMMER														
Average of Individual Models	-1.129	-2.144	-0.555	-2.603	-0.262	0.425	-0.196	0.170	0.257	0.031	0.166	-0.007	-0.113	0.920
Pooled (Simple)		-0.138	-0.170	-0.067	-0.089		-0.079*		0.024	0.032				0.550
Pooled (Adjusted - Random Effects)			-0.479	-1.8144										0.2595
FALL														
Average of Individual Models	-0.796	-0.057	-1.338	-5.798	0.954	-0.725	0.080	0.072	-0.062	0.194	0.571	-0.091	0.196	-0.450
Pooled (Simple)	-0.020	-0.204	-0.037	0.003			0.050				-0.008			0.265
Pooled (Adjusted - Random Effects)		0.2507		-2.3968			0.176*		-0.15					-0.3205

* Route was not significant as a main effect, but kept in the model to investigate interaction of variables